Near Surface Phenomena in the Inhomogeneous Coastal Boundary Layer

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LONG-TERM GOALS

The long-term goals of the research are to understand and assess the effects of atmospheric phenomena on the detection of targets at low altitudes over sea in coastal environments with long range infrared search and track (LR-IRST) systems. Atmospheric propagation effects considered are transmission losses due to aerosols and water vapour, blurring and scintillation due to turbulent fluctuations of air temperature and changes in refractivity due to vertical temperature gradients.

OBJECTIVES

The objectives of the research performed in the framework of the Grant are:
- to describe the aerosol source function in coastal areas at short fetches;
- to quantify the effect of the surf zone on the production of sea spray aerosol;
- to determine the turbulence and refractivity in the inhomogeneous coastal boundary layer and their effects on imaging of low altitude point targets;
- to improve the description of the aerosol size distribution as function of height and meteorological parameters.

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APPROACH

Aerosol source function.
Aerosol particle size distributions were measured during EOPACE (Electro-Optical Propagation Assessment in the Coastal Environment) experiments on piers, boats and ships. A suitable selection of these data will be used to formulate expressions for the aerosol source function, and relate the results to meteorological and wave parameters. In addition, data from a variety of other locations will be used in this effort to cover situations and conditions that are representative for 'typical' scenarios and thus allow for extrapolation of the results to other areas. When bubble size distributions are also available, an attempt will be made to discriminate between bubble-mediated production of aerosols and spume droplet production [De Leeuw et al., 1996].

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Surf-zone production of aerosols.
During the EOPACE Surf experiments in San Diego (Scripps Pier, La Jolla) and Monterey (Moss Landing Marine Institute), the production of aerosols in the surf zone was quantified from particle size distribution measurements at different levels upwind and downwind from the surf zone. Prior to these measurements, the optical particle counters used in these surf experiments were calibrated and intercompared, to avoid compatibility problems that are frequently observed between un-like instrumentation.

Turbulence and refractivity.
Optical turbulence and refractivity are due to different phenomena, i.e. turbulent fluctuations of the air temperature and variation of the mean air temperature with height. During EOPACE IOP's in Monterey and San Diego, over-water transmission links were established between, respectively, Moss Landing and Monterey(path length 22 km) and between Imperial Beach Pier and the Point Loma submarine base (path length 14 km). Visible and IR sources were mounted on the piers. The turbulent fluctuations of the transmitted signals and the positions of the images were measured with camera systems in both the IR and in the visible. Simultaneously, meteorological and aerosol parameters were measured to support the analysis and understand the observed phenomena, and to test propagation models such as IRBLEM [Forand et al., 1998]. A problem is the atmospheric inhomogeneity in off-shore flow, affecting temperature and humidity profiles, and the presence of waves. Data used include those from buoys along the propagation path, and those recorded using a small boat equipped with meteorological instrumentation and IR sources. The latter allows for the determination of the range dependence of the turbulence and refractivity effects.

WORK COMPLETED

During FY98, TNO-FEL participated in EOPACE IOP8, which took place in Duck (NC) in February 1998. IOP8 was a ‘small-scale’ experiment involving only 2 of the ‘regular’ EOPACE participants. The experiments in Duck were regarded as a test for a full-scale EOPACE experiment in 1999, to validate surf experiments on the Californian coast (La Jolla, Monterey, San Diego Bay). The attraction of the Duck site is the 600-m long pier and the supporting measurements of environmental parameters such as waves, bottom topography and meteorological data. During the Duck trial, TNO-FEL only measured profiles of aerosol particle size distributions over the surf with Rotorods, to complement the SPAWAR measurements with optical particle counters. Other important information is the evolution of the aerosol plumes measured with lidar by NRL, and bubble information measured with acoustical techniques by NRL. The TNO-FEL optical bubble measuring system could be used during only a very short time because the instrument was damaged in the violent surf.

The analysis of the earlier EOPACE experiments on surf aerosol production, long range transmission and scintillation, and air mass characterisation has been continued. Results are summarised below.

RESULTS

Surf-produced sea spray aerosol.
During the Surf experiments in La Jolla (1996, 1997) and Monterey (1996), particle size distributions were measured by TNO-FEL at the base of the pier and by University of Sunderland (CMAS) at the end of the pier. From comparison of the results in on- and off-shore winds, empirical relations were

developed for the production of sea spray aerosol over the surf zone [De Leeuw et al., 1997; Neele et al., 1997; 1998a; 1998b; 1998c]. Primarily, only the wind speed was identified as a parameter. Together with Delft Hydrolics, a model was developed that describes the aerosol production over the surf in terms of the wave spectrum measured in deep water and the bottom topography [Neele et al., 1998b; 1998c]. This model is based on a parameterisation of the aerosol mass flux over the surf derived from lidar measurements at a Polish site [Petelski and Chomka, 1996; Chomka and Petelski, 1997]. The surf-production model reasonably predicts the observed aerosol fluxes in many cases, and even the evolution of the fluxes over a period of several hours. However, in other cases the model predictions may be more than one order of magnitude off from the observations. This may be due to the use of inappropriate wave spectra, e.g., for the experiments in Monterey Bay, but also other factors may play a role. It is noted that the parameterisation used in the model needs improvement.

The effect of the surf-produced sea spray aerosol on the extinction was estimated using aerosol transport models, in the framework of a PhD study [Vignati, 1999]. A simple line source model, taking into account diffusion and deposition, showed the horizontal extent of the surf-produced aerosol [De Leeuw et al., 1997a; 1997b; Neele et al., 1998a]. In a following effort, the Coastal Aerosol Transport model (CAT) is now under development, to describe processes in a column advected out over the sea [Vignati, 1999; Vignati et al., 1998]. The aerosol is transported in the vertical by diffusion and gravitational effects, and deposition takes place at the surface. Surface production of sea spray aerosol is accounted for, and the model is initialised with the vertical aerosol distribution at the land-sea transition, i.e. the surf produced aerosol and a continental aerosol distribution. Initial exercises with the model show the relative contributions of the surf-produced and surface-produced sea spray aerosol, and the distances over which the surf aerosol dominates the aerosol concentrations [Vignati et al., 1998]. Preliminary results from a small-scale surf-characterisation experiment in Duck (NC) show that the model may reasonably predict observed plume transport, at least qualitatively.

Transmission and scintillation.

Transmission and scintillation were measured by TNO-FEL over a 22 km path over Monterey Bay between Monterey and Moss Landing in 1996, and over a 15 km path across San Diego between the Point Loma Subase and Imperial Beach Pier in 1996 (April and November) and 1997 [De Jong et al., 1996; 1998a; 1998b; 1998c; Zeisse et al., 1997; De Jong and de Leeuw, 1997; Forand et al., 1997; 1998]. These measurements span several seasons with a wide variety of atmospheric conditions. Anomalous transmission effects were observed during all experiments. The base transmission was reasonably well forecasted with MODTRAN, but large excursions were observed with very high transmissions due to refraction and atmospheric lensing which cannot be explained by either MODTRAN or IRBLEM [De Jong et al., 1998c; Forand et al., 1998]. The anomalous transmissions occur over periods varying from minutes to hours. Scintillation was observed at time scales from seconds to minutes, which apparently cannot be explained by current theory [De Jong et al., 1998c].

Air mass characterisation.

TNO-FEL participated in the air mass characterisation experiments in 1996 and 1997 with aerosol retrievals using AVHRR data, in a strong cooperation with the Naval Postgraduate School (NPS) in Monterey, and lidar measurements of aerosol backscatter profiles. The aerosol optical depths clearly show the variations off the Californian coast, and the lidar profiles show the vertical layering. During the 1996 air mass characterisation experiment, the aerosol optical depth was mainly due to aerosols contained in layers above the marine boundary layer, which appeared very shallow. An elevated layer

was advected off shore in the Santa Ana condition encountered during the experiments. However, elevated aerosol layers are not unusual as demonstrated by the TARFOX data [Veefkind et al., 1998]. The air mass characterisation data are analysed in a strong cooperation with NPS and CMAS, taking into account the meteorological situation [Veefkind et al., 1997; Wash et al., 1997; 1998; Jordan et al., 1998].

IMPACT

The results can be used to assess the effects of the atmosphere on the performance of thermal imagers over sea, and in particular the performance of LR-IRST systems.

RELATED PROJECTS

The EOPACE results of TNO-FEL are exchanged with other EOPACE participants. Cooperations are underway to commonly analyse the EOPACE data. The efforts described above are in conjunction with other projects addressing electro-optical propagation over sea in coastal environments, in part basic research, in part applied research, including work on long-range transmission, IRST and backgrounds. Data are used from other areas, e.g. the North Sea, the North Atlantic, the Mediterranean and the Baltic. These projects are supported by the Netherlands Ministry of Defence, the EU or other funding agencies.

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IN-HOUSE/OUT-OF-HOUSE RATIOS

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